EASTMAN CHEMICAL COMPANY

KINGSPORT PLANT

CHEMICALS FROM COAL OPERATIONS

1983 – 2000

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ABSTRACT:

The Chemicals from Coal Facility of Eastman Chemical Company began operation in 1983 using various purchased technologies such as Texaco gasification and Linde AG Rectisol gas clean-up as well as Eastman developed technologies for chemical production. Initially, the plant was designed to produce approximately 500 million pounds per year of acetic anhydride and acetic acid to supply half of Eastman's acetyl raw material needs. The facility was expanded in 1991 and additional debottlenecking brought the capacity to the current level of approximately 1.14 billion pounds per year. Two 450 cubic foot gasifiers are campaigned to give gasifier system uptimes in excess of 98% with a maximum rate of approximately 1350 tons per day of coal. The gasifiers are operated at 150% the original design basis. The facility is now the sole source of raw materials for Eastman's profitable acetyl stream and is operationally and economically a proven means of producing acetyl chemicals from coal.

INTRODUCTION

This paper reviews the progress of the Chemicals from Coal Facility of Eastman Chemical Company. Eastman Chemical Company has nearly $5 billion in annual sales and currently has approximately 15,000 people working to produce over 400 different chemicals, fibers, and plastics. The corporate headquarters are located in Kingsport, Tennessee also the site of Eastman's largest manufacturing unit, Tennessee Eastman Division.

The Chemicals from Coal Facility is also located in Kingsport on a 55-acre site adjoining Eastman's existing chemical complex. The facility began operation in 1983 after four years of engineering and construction and more than eight years of work to identify, develop, and assemble the technologies necessary to make the operation viable.

The Chemicals from Coal Facility was the first use of a commercial Texaco coal gasifier to provide feed gas for the production of acetyl chemicals. In addition to the first Texaco coal gasifier, the project was the first use of new technologies developed by Eastman to produce methyl acetate and the final product acetic anhydride.

For this significant advancement in acetyl chemicals production, in 1985, Tennessee Eastman was awarded the prestigious Chemical Engineering Kirkpatrick Award.

In November 1995, the American Chemical Society recognized the Chemicals from Coal Facility as a National Historic Chemical Landmark.

Acetyl chemicals are an important part of Eastman Chemical Company's overall portfolio of chemicals, fibers, and plastics, but they are particularly important to Tennessee Eastman Division. Five of the seven manufacturing divisions at the Kingsport site depend on acetyl raw materials. Approximately 3.2 million pounds per day of "new" acetic anhydride and acetic acid are produced in the Chemicals from Coal Facility and are used in the production of cellulosic plastics and fibers that end up in consumer products like photographic film, tool handles, paints, and cigarette filters. Direct sales of anhydride and acid are used in a wide variety of industrial and pharmaceutical applications (Figure 1).

HISTORY

Prior to the completion of the Chemicals from Coal complex, all of Eastman's acetyl raw materials were petroleum and natural gas based. Ethane, propane, and naptha were cracked to form propylene and ethylene. The ethylene was converted to acetaldehyde at Texas Eastman Division. The acetaldehyde was transported to Kingsport and further oxidized to acetic acid and then converted to acetic anhydride via natural gas fired, ketene cracking furnaces.

The oil shortages of the 1970's and specifically the oil embargo of 1973 provided the incentive for Eastman to begin to explore the possibility of supplying the acetyl stream from coal mined in nearby Southwest Virginia and Eastern Kentucky, instead of oil.

Eastman engineers along with Bechtel as the contractor began to identify existing technologies as well as developing new ones to make the dream a reality. The first gasifier start-up occurred on June 19, 1983 and by April of 1984, the entire complex was in full production. The original capacity of the plant was needed to supply one half of Eastman's acetyl demand. After several years of successful operation, the decision was made to expand the facilities to meet the entire acetyl demand from coal (Figure 2).

This expansion was completed in 1991 and was accomplished by building essentially duplicate downstream chemical plants and clean-up equipment. However, the gasification plant was not significantly expanded. Increased rates through the gasifiers were achieved by debottlenecking key parts of the gasification process. In addition, the percentage of raw gas processed in the shift reactor to make methanol synthesis gas was reduced and diverted to the higher value acetic anhydride production. In this way, the acetic anhydride production was doubled without a two-fold increase in raw gas produced. However, approximately 25% of the internal methanol demand is now met via outside purchases.

After this "Phase II" expansion, the gasifiers ran at about 128% of the original design capacity. Today, through years of continual debottlenecking, the gasifiers run at a maximum of 150% of the original design (approximately 1300 tons per day of coal).

Table 1 is a chronological listing of the historical milestones of the complex.

DESCRIPTION OF PLANT

The Chemicals-from-Coal complex is divided into two major operating areas – synthesis gas production and chemicals production. There were nine plants in the original complex. Four more plants were added in the Phase II expansion.

The synthesis gas production area contains the coal handling/slurry preparation plant, the gasification plants, the Rectisol gas clean-up plant, the CO/H2 separation plant, and the sulfur recovery plant. Oxygen is supplied by Air Products and Chemicals, Inc., from an air separation plant adjacent to the Eastman plant.

Oxygen and coal are supplied to either of two 450 cubic foot Texaco quench gasifiers (Figure 3). Raw gases produced are split into two process streams. About one third of the raw gas is routed to the shift reactor to produce enough hydrogen to make the correct stoichiometric composition for methanol production. Both gas streams are cooled in the cooling trains and sent to the Rectisol plant. Steam, at a rate of approximately 200,000 pounds per hour, is produced in the cooling trains and utilized in downstream processes.

Carbon dioxide and hydrogen sulfide are removed from the gas streams in chilled methanol absorbers (Figure 4). The hydrogen sulfide is sent to a Claus/SCOT recovery unit for recovery of sulfur. Carbon Dioxide is vented to the atmosphere. The process gas stream is sent to the CO/H2 cryogenic separation plants to produce the carbon monoxide used in the acetic anhydride plant.

The CO/H2 gas mixtures received from the cryogenic separation units are mixed with the gas stream from the shifted gas train and sent to the methanol plants.

The chemicals production area contains the methanol plants, methyl acetate plants, acetic anhydride plants, and catalyst recovery plants. Methanol is produced in a Lurgi unit as well as a new "Liquid Phase" unit, which is a joint venture between Eastman, Air Products and Chemicals Inc., and the Department of Energy. The methanol is reacted with acetic acid to produce methyl acetate in a proprietary Eastman process. Methyl acetate is reacted with carbon monoxide in a proprietary catalytic process to produce acetic anhydride with co-production of acetic acid.

KEY OPERATIONAL ISSUES

Production rate, reliability, maintenance cost, and safety are of primary importance to the operation of the Chemicals-from-Coal facility. Of course there are many other important areas to consider, but the success in these four areas is key to the acetyl business.

Production Rate

Because the acetyl stream is such an important part of Eastman's overall business and the demand for these products is very high, essentially every pound produced can be sold in the market place. So naturally, the pressure to increase production rate is always present. Also, the incremental cost to make additional product is much lower than the fully allocated cost, so the profit margins for incremental production are large. By debottlenecking key areas of the gasification process, the production rate has been increased from 128% of original design (basis for the Phase II expansion) to recent levels as high as 150% of the original design. Figure 5 gives the total gas production for the last several years. The steady trend upward indicates that the accomplishments that have been made by continual debottlenecking.

The challenge for the future will be to continue this trend. However, this will be increasingly difficult as we begin to reach bottlenecks in all the plants simultaneously.

Reliability

Perhaps more important than production rate is reliability. Outages of the gasification complex result in downtime in the chemicals production areas, and depending on the duration, can drastically affect production in the majority of the operating divisions at Tennessee Eastman. The primary measure of reliability is percent uptime (or gas availability to the chemical plants). Since 1986, the gasifier uptime (not including planned complex shutdowns every two years) has consistently been above 98% (Figure 6). To achieve this high level of reliability, a two-gasifier design is key. Each time a gasifier is taken off-line, it is "turned around" (i.e., made ready for the next run) typically within 7 to 14 days. Then, if a problem develops on the operating gasifier which doesn't cause immediate shutdown, the spare gasifier can be started and put online without interruption of the gas supply to the downstream plants.

There are a number of operating and maintenance problems that can cause a gasifier to shutdown. See Figures 7 and 8 for historical and recent shutdown causes. In past years, the fuel injector (often referred to as “burner”) has been the primary cause for shutdown. However, Eastman experts have had recent breakthroughs in feed injector design, which have effectively prolonged the life of a burner far beyond the run life of other system components. At the time of this writing, the run length is 75 days and counting.

It appears that the next run length limit will be due to plugging in the quench and black water systems, specifically the steam generators. Projects have been identified to alleviate this bottleneck.

Key to this continual improvement is a “run review” held after each shutdown. Essentially, experts perform an autopsy of the run, identify key problems, analyze critical data, and generate projects to improve the process performance.

Maintenance Cost

Of the operating cost factors, maintenance cost is the highest controllable cost. However, due to reliability, capacity, and safety demands, there has always been a struggle to find the right level of maintenance support. The Chemicals from Coal facility has historically been supported by around the clock maintenance including 10 to 12 mechanical, electrical, and instrumentation mechanics and an expanded day shift crew. However, Eastman has recently cut back on the level of off-hour support in an effort to reduce overall maintenance costs. Eastman has adopted a philosophy of performing a higher percentage of “planned maintenance” and continually assessing the maintenance need while working to identify and implement reliability projects to take work out of the system.

As a result, turnaround times have increased but because of the lower number of failures (a product of reliability projects) 2000 has been the most productive year on record. Additionally, maintenance costs have been reduced by 10 – 15%.

One of the most expensive items in the annual maintenance budget is refractory replacement. Refractory wear is obviously related to temperature and slag properties, but our experience has shown that it is also proportional to gasifier rate. Even though the refractories have improved over the years, the run time per liner has gone down due to the increased throughput. However, the amount of production per liner has remained relatively constant. Currently, the approximate run time per liner is 7,000 hours. Due to the cooler operating temperatures allowed by some of the newer coals, the refractory life is expected to improve in the future.

Safety

Eastman Chemical Company is committed to providing a safe work environment for its employees. Considering the potential hazards that exist in the complex (high pressure, toxic gases, rotating equipment, high level of maintenance activity, extreme high and low

temperatures), this is a considerable challenge and is always a consideration in everything we do. The past safety record has been excellent. Currently, the Acid Division, including the Gasification Complex, has an OSHA recordable rate less than 1.0.

The gasifier system, as well as other critical downstream processes, is equipped with a well instrumented safety system that will automatically shut off the feed if any unsafe conditions are detected. In order to maintain the safety of the operation without having false shutdowns, redundant instrumentation is typically used.

Area on-line CO and H2S monitors are located throughout the operating area to warn of leaks that could create hazardous conditions. In addition, personnel entering the plants wear portable personal CO and H2S detectors equipped with alarms.

MAJOR PROCESS IMPROVEMENTS AND ENHANCEMENTS

Over the seventeen years that the complex has been in operation, many company resources have been poured into efforts to improve the process. The improvements indicated by the previous charts do not tell the full story. Some of the major process improvements and enhancements are discussed briefly below.

Burner Design Improvements

The major cause of shutdown has historically been failure of the feed injector. High temperature sulfidation corrosion has been blamed for the failures. Recent breakthroughs in injector design combined with rigorous inspection and checkout of various feed system components have resulted in greatly improved fuel injector life. Eastman Chemical Company has received 6 patents dealing with fuel injector improvements and is continuing to develop know-how in this important area of process reliability. The most recent campaign utilized a gasifier that operated continuously for 77 days on the same feed injector (Figure 9). This is more than twice the historical average run life. It is expected that runs in excess of 100 days will be achieved.

Complex Shutdown Planning and Execution

The entire Chemicals-from-Coal complex is shutdown for maintenance once every two years. During the 1999 shutdown, approximately 560 jobs were completed on the synthesis gas areas alone. Through careful planning and execution, these outages have been minimized to approximately 9 days in duration. The industry standard for acetyl plants for such major turnarounds is usually 2 to 3 times this amount of time and typically does not include the complexity of a Chemicals from Coal process.

Alternate Feedstocks

Eastman has successfully operated gasifiers feeding petroleum coke, numerous liquid organics, and a wide variety of coals. Sulfurless startups are accomplished using liquid organic feedstocks. A unique system for qualifying coals for use has been developed. In-house slag viscosity testing has been key to this process. As a result, Eastman has been able to select better performing, lower cost coals from the numerous varieties of coals available. Coals allowing more product gas per ton, lower ash fusion temperatures, and forgiving slag viscosity profiles have been identified and are currently in use.

State of the Art Distributive Control Systems

The gasification complex has been retrofitted with a state of the art Honeywell distributive control system (GUS). This system has allowed complex algorithms to be added to the feed controls system as well as other systems in the plant. Additionally, Eastman's Controls Technology group has developed and implemented Model Predictive Control (MPC) techniques to fully utilize the plant capacity and maximize gas production without operator intervention.

Switching Gasifiers

When it is necessary to switch from one gasifier to another and a complete shutdown is not required, gas flow from the "new" gasifier is valved into the cooing train while the gas from the "old" gasifier is valved out. This has historically been a slow, careful process taking a few hours. A "quick switch" procedure has been developed which allows this transition in less than one hour. This improved process also minimizes impact to downstream plants allowing production to continue and reduces the waste gas produced during switches. Figure 10 shows the number of business interruptions (loss of gas supply to downstream plants) since startup. When compared to the number of gasifier shutdowns, Figure 9, the benefit of skilled "switching" techniques is evident.

SUMMARY AND CONCLUSIONS

The Chemicals from Coal Facility continues to be a commercially viable operation for the production of acetyl chemicals from coal. A testament to its reliability and cost efficiency is Eastman's reliance on this facility as the sole source of raw materials for one of the largest streams within the company (in terms of earnings and pounds). Needless to say, Eastman Chemical Company's success depends to a great degree on the profitability of the Gasification complex.

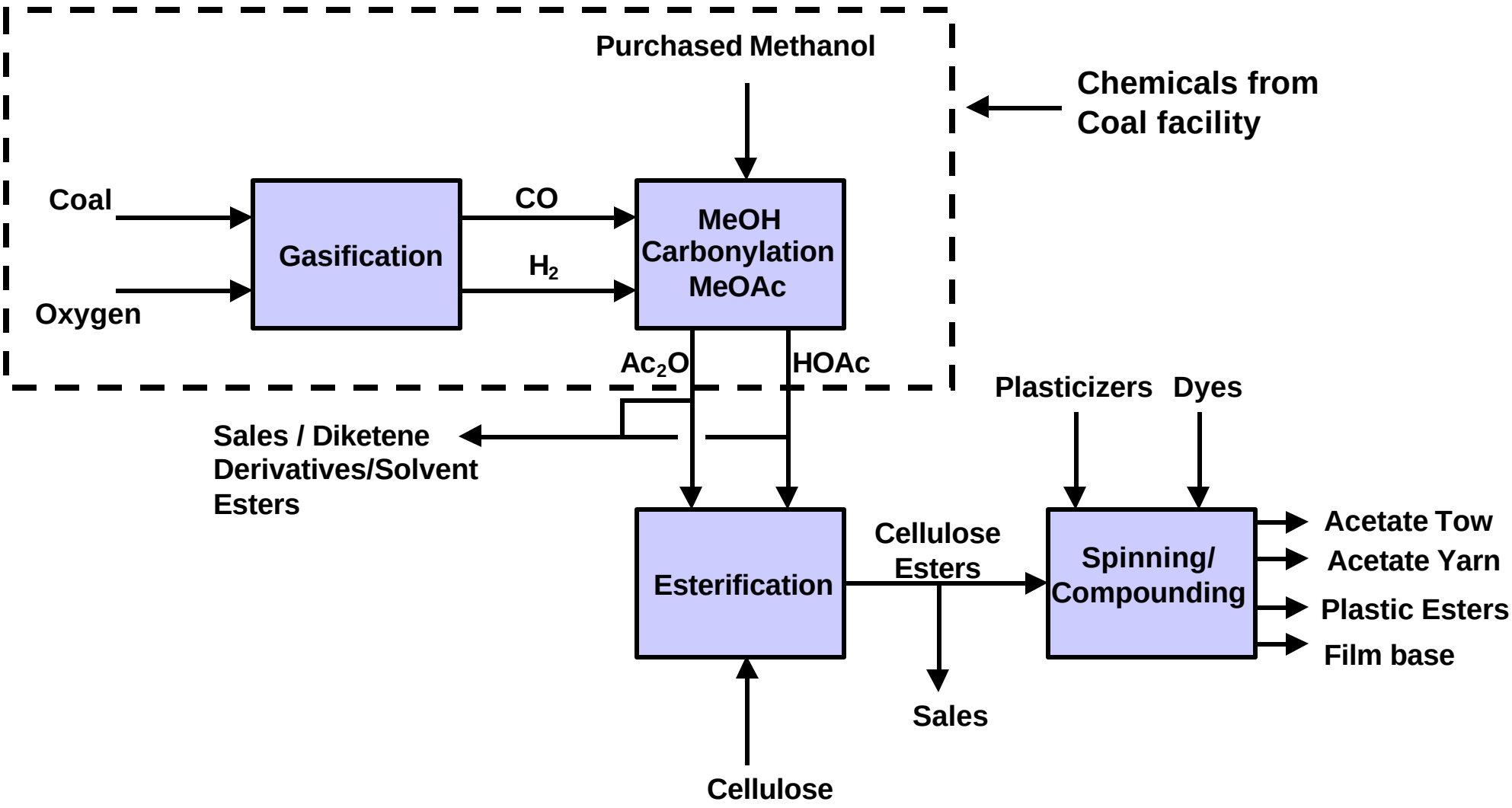
The operation (particularly the gasification process) is maintenance intensive, but can be managed to provide the proper balance between cost and reliability. Eastman has, through years of work, greatly improved the reliability, production, and thus the profitability of this process.

Eastman's experience and expertise in Gasification and Chemical Synthesis technology have made the Chemicals-from-Coal Complex a world class operation.

References:

1. L. T. Arms, “Eastman Chemical Company Gasification Plant Expansion and Operation Summary,” Paper presented at the Eleventh Worldwide Texaco Licensee Symposium, New York, NY (October 1994).
2. T. L. Mitchell, W. L. Trapp, “Eastman Chemical Kingsport Plant – Chemicals form Coal Operations 1983-1997,” (October 1997)

Figure 1: Acetyl Flow at Tennessee Eastman Division



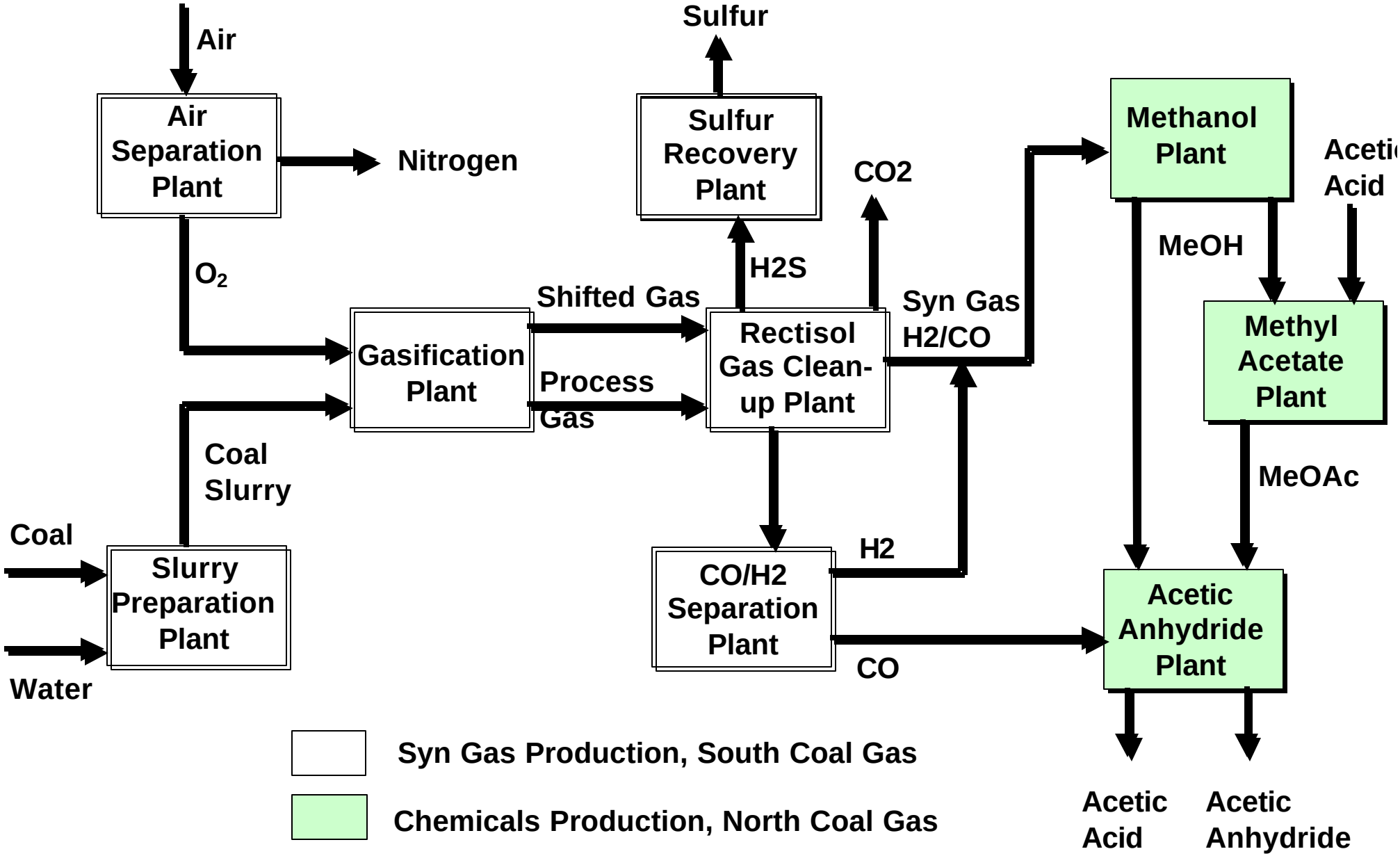


Figure 2: Chemicals from Coal - Block Flow

Table 1

History of the Chemicals from Coal Facility

1970 Eastman scientists conducted a prescient planning study for chemical feedstocks.

1973 Oil embargo: Oil prices increase (acetic anhydride produced from oil based chemicals).

1975 Eastman started R&D on the use of coal based anhydride process.

1977 First small pilot plants began operation.

1978 Bechtel Corporation awarded contract for EPCM for the Chemicals from Coal Facility

1983 Construction Complete

March	Coal grinding and slurry operation
May	Methyl Acetate plant startup
June 19	Startup of Gasifier #1
July 19	Methanol Production started
Aug 12	Startup of Gasifier #2
Oct 6	First production of acetic acid

Oct 83 – July 84 Gasifiers onstream 85% of the time and acetic anhydride operated 75% of the time

1984 July – 2 week shutdown to install improvements necessary for full capacity
July – December – Gasification plant on stream 97% while acetic anhydride plant on stream 95.5%

1988 Bechtel started the EPC work to double the acetic anhydride production

1991 Construction of the Phase II expansion completed (1.2 billion pounds per year production; 1200 tpd coal)

2000 Rates reach 150% of original design; Gasifier run lengths exceed 75 days. (1300 tpd coal -> chemicals)

Figure 3: Simplified Flow Diagram - Gasification

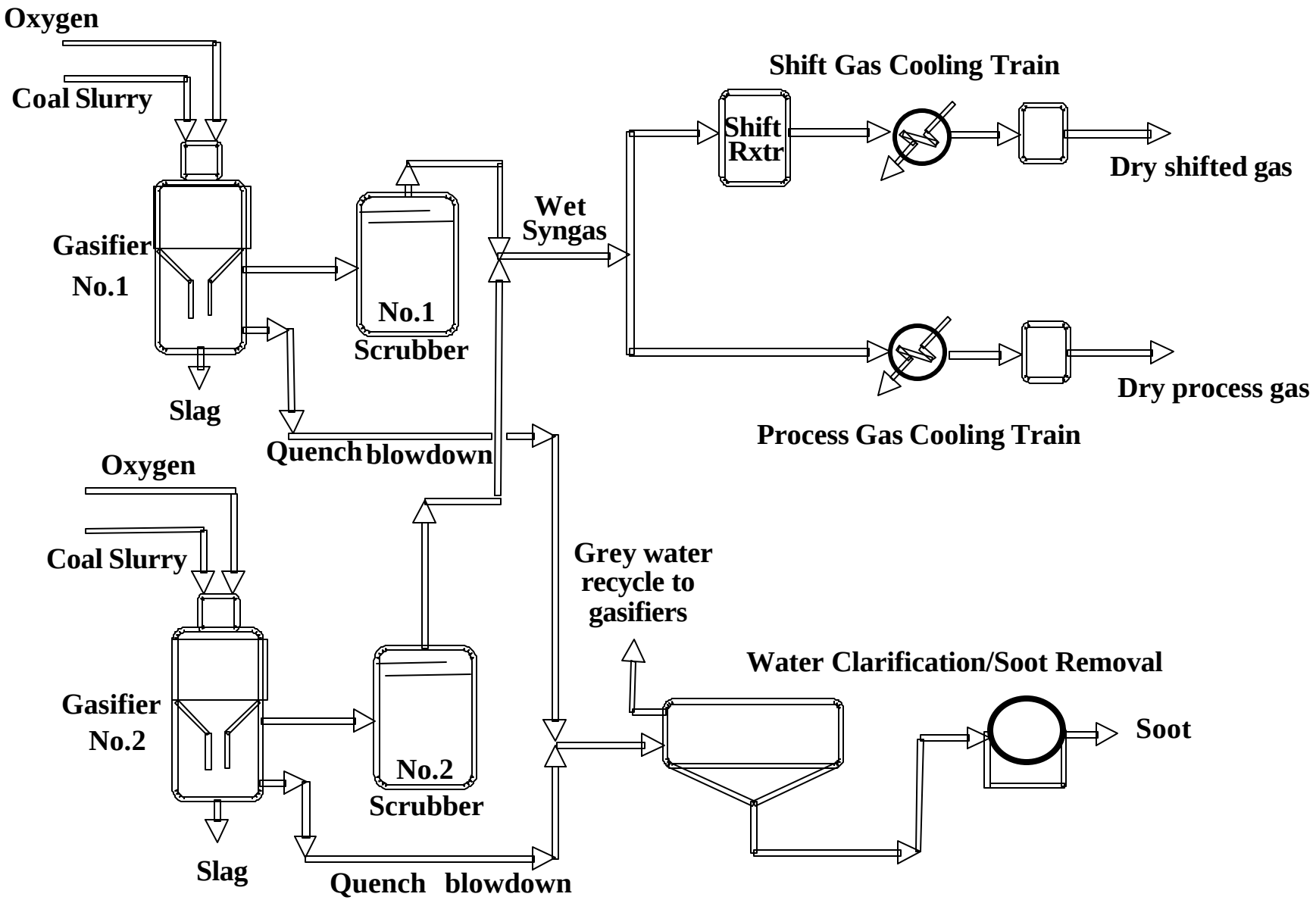


Figure 4: Gas Clean-up, Recovery

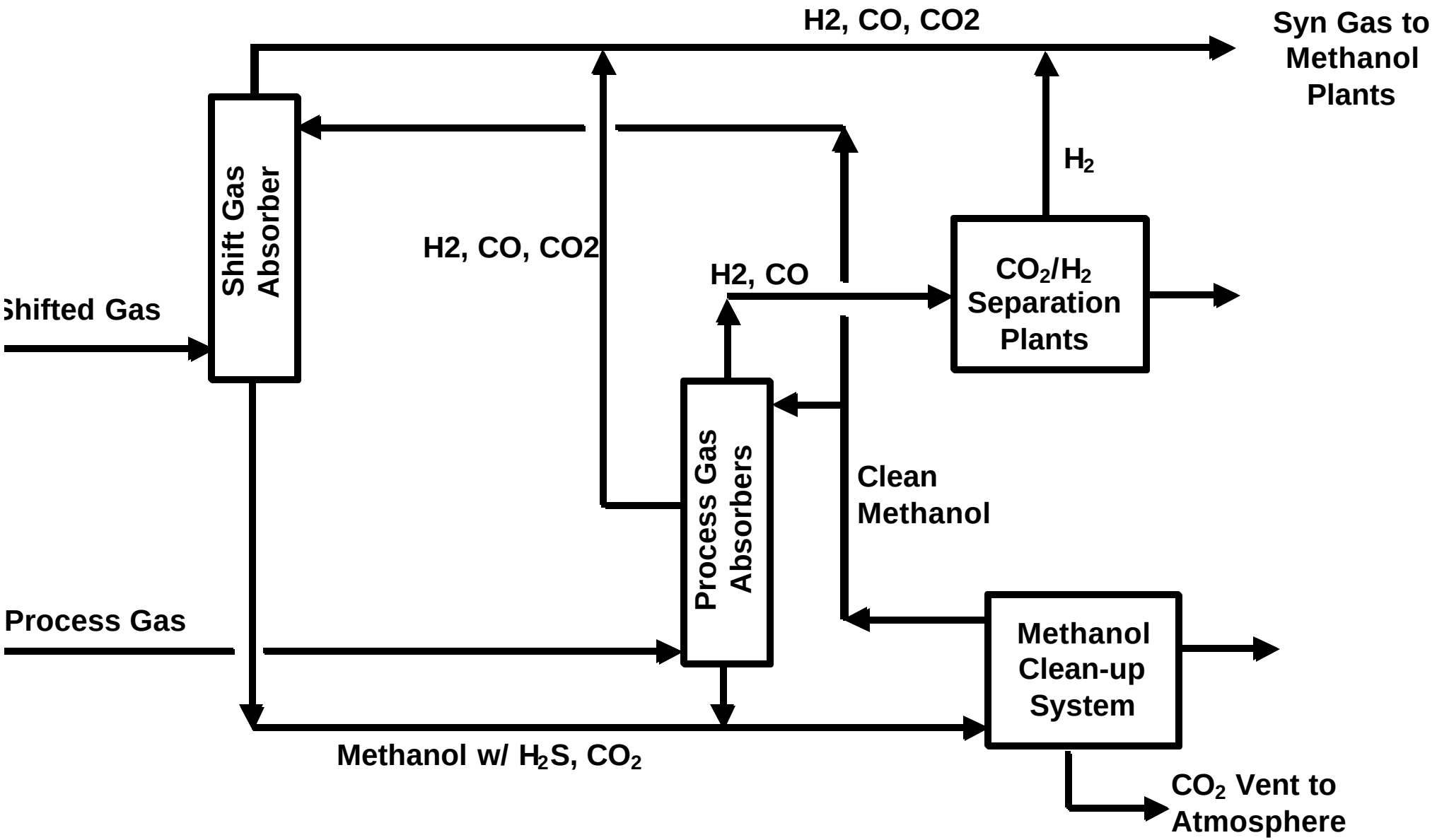


Figure 5: Yearly Gasifier Production Rate

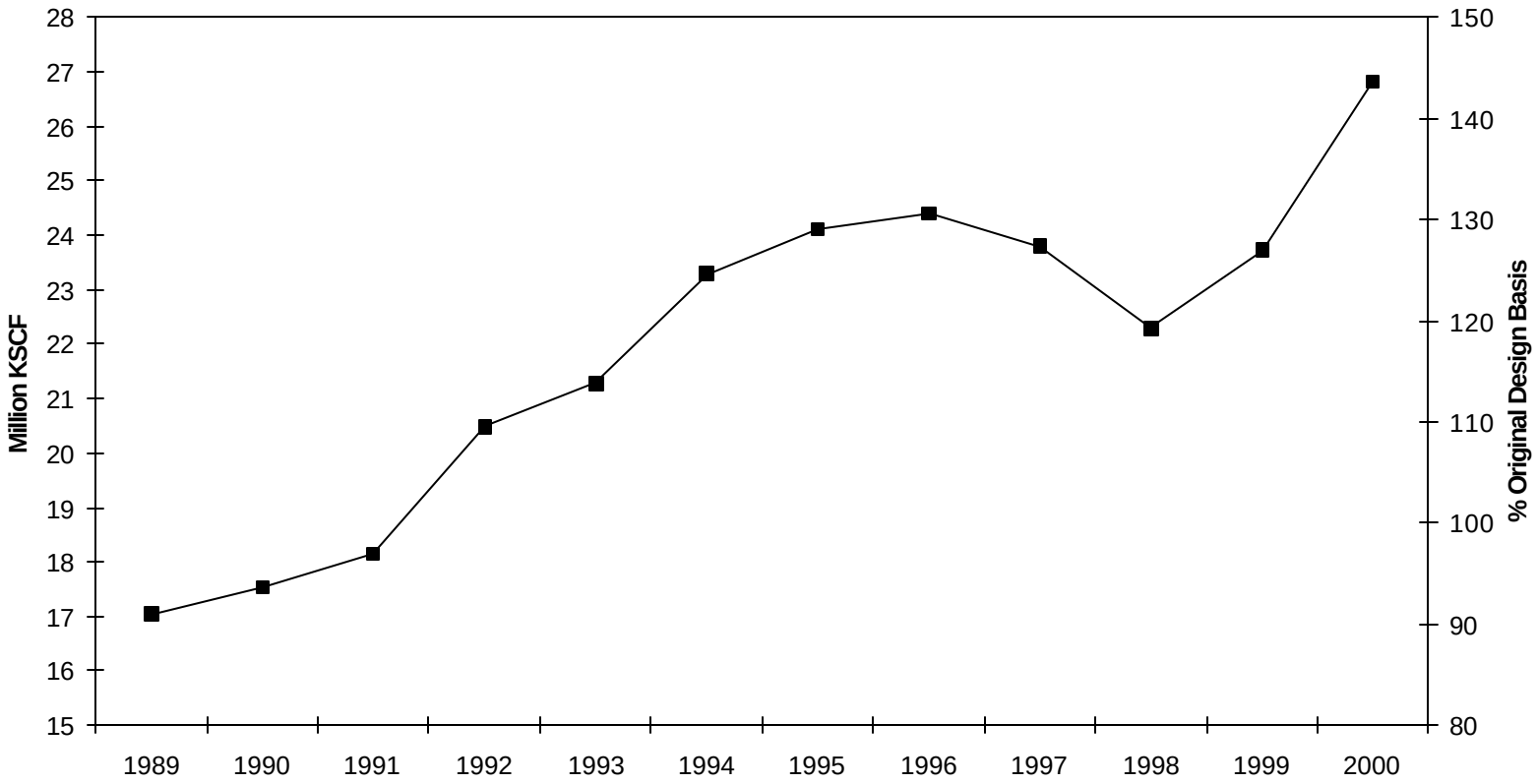


Figure 6: % Uptime
(w/o Planned Biannual Shutdown or Power Failures)

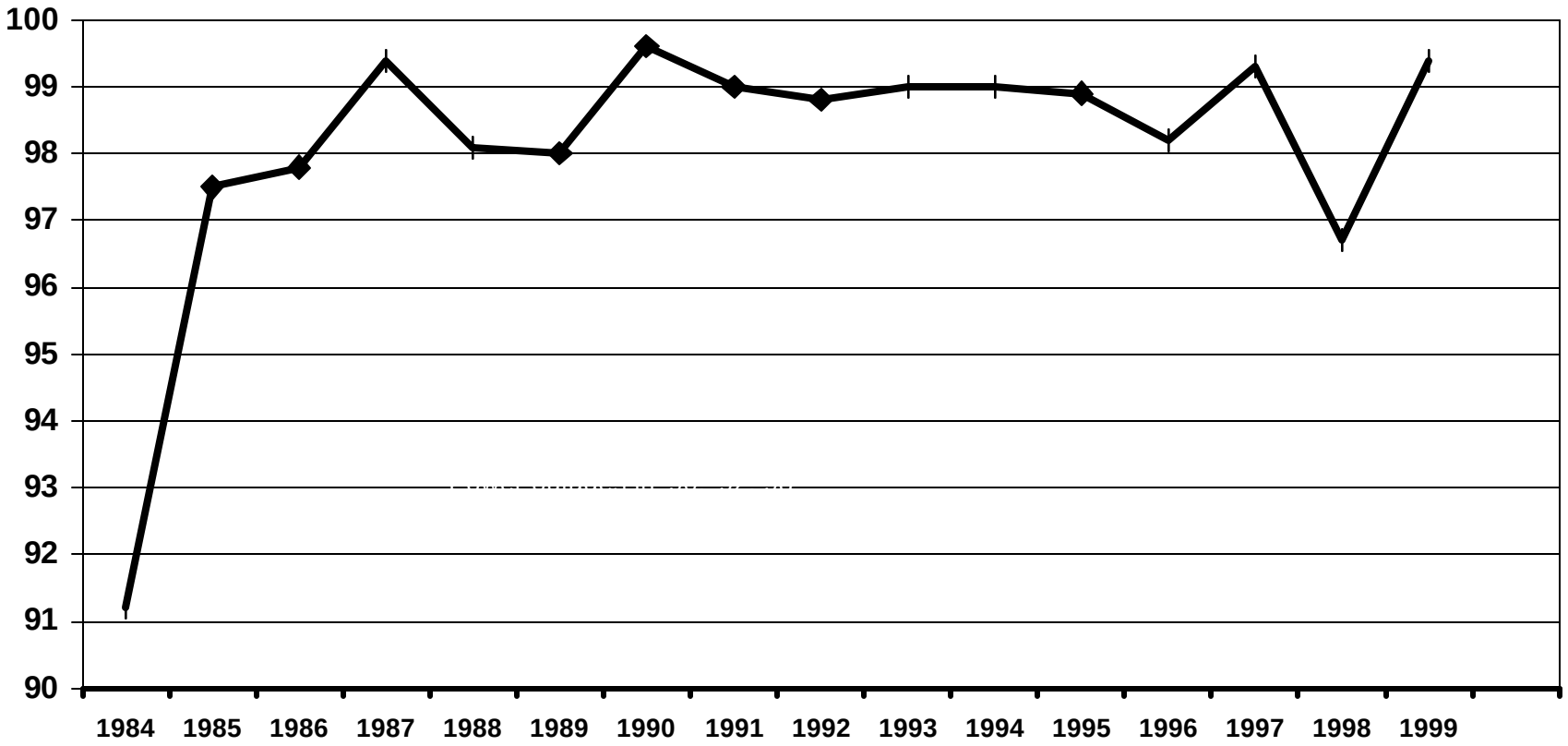


Figure 7:
Top 10 Shutdown Causes
1983 – 2000

Rank	Shutdown Cause	% of total
1	Feed Injector Failure	18.7%
2	Slurry Feed Pump	15.2%
3	Planned Switch	10.9%
4	Low Quench H2O Flow	6.6%
5	Low Slurry Flow	5.8%
6	Low level in Gasifier	4.8%
7	O2 Leak	4.1%
8	PSV failure	2.3%
9	Dip/Draft Tube	1.8%
10	DCS - PLC failure	1.8%

Figure 8: Shutdown Causes
1999 – 2000

1999

Description	Count
Planned switch	3
Seal water supply pump	2
Slag drag failure	1
Relief valve failure	1
Plugged quench ring	1
Lockhopper valve problems	1
High temp on injector jacket	1
Feed Injector Failure	1

2000 through September

Description	Count
Feed injector failure (prior to new design)	2
Low quench flow (pump failure)	1
Plant wide power failure	1
Black Water exchanger fouling	1
Oxygen Plant Shutdown (Lightning)	1

Figure 9: Gasifier Run Length (Days)

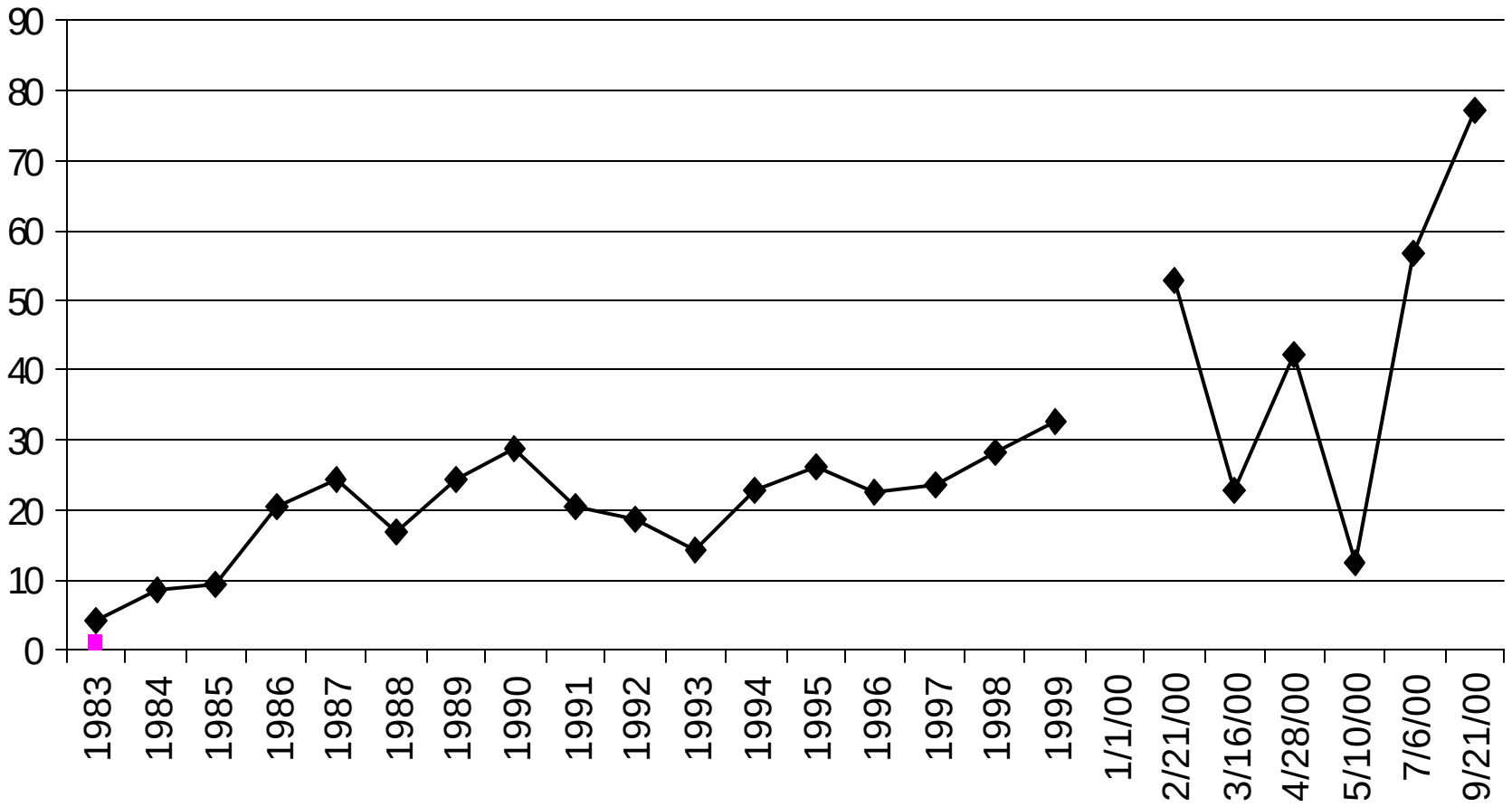
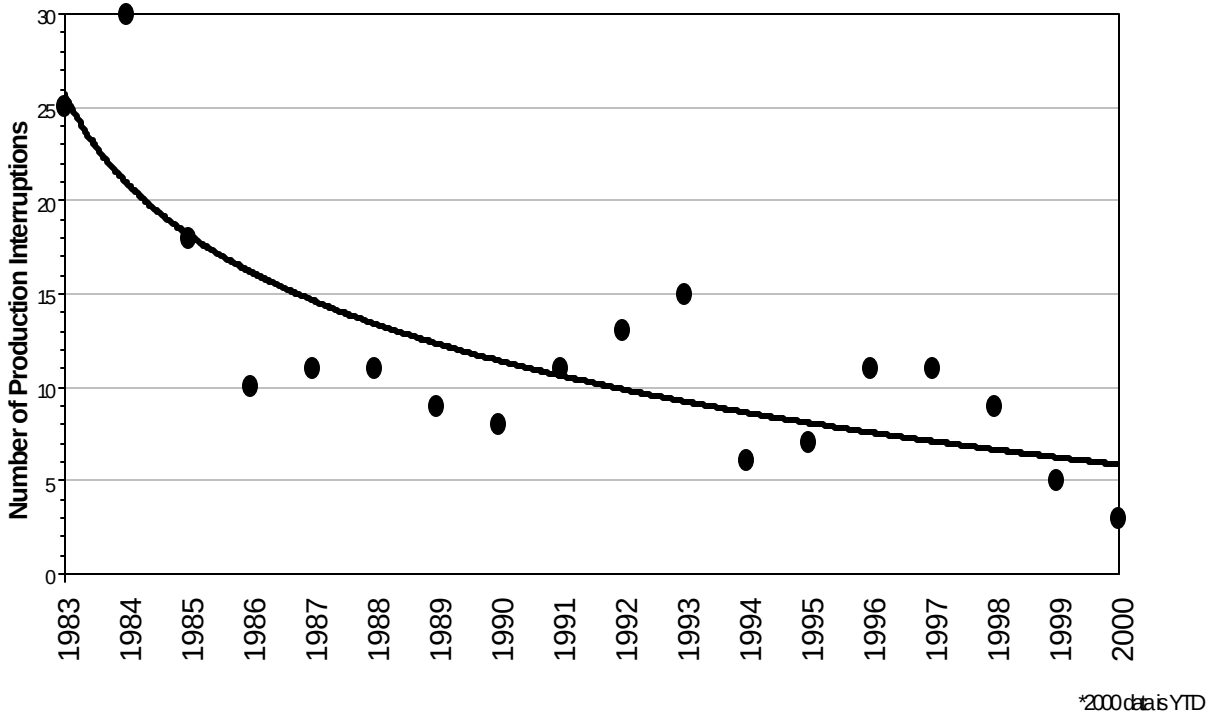


Figure 10: Production Interruptions

1983 to Present



*2000 data is YTD